Search for Dijet Resonance in pp Collisions at CMS and ATLAS

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Search for Dijet Resonance

- The results of Dijet Resonance search based on 315 nb^{-1} data from ATLAS was accepted by PRL.

  http://arxiv.org/abs/1008.2461v2

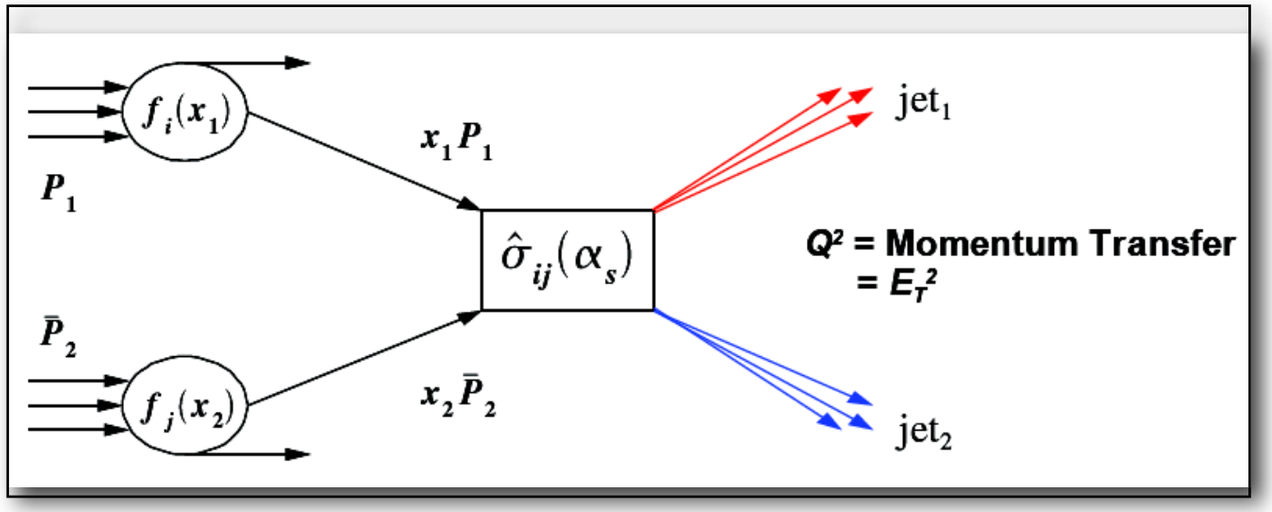
  - v1, 14 August 2010
  - v2, 29 September 2010

- The results of Dijet Resonance search based on 2.88 pb^{-1} data from CMS was submitted to PRL. It is first research and jet paper from CMS.

  http://arxiv.org/abs/1010.0203

  - v1, 1 October 2010

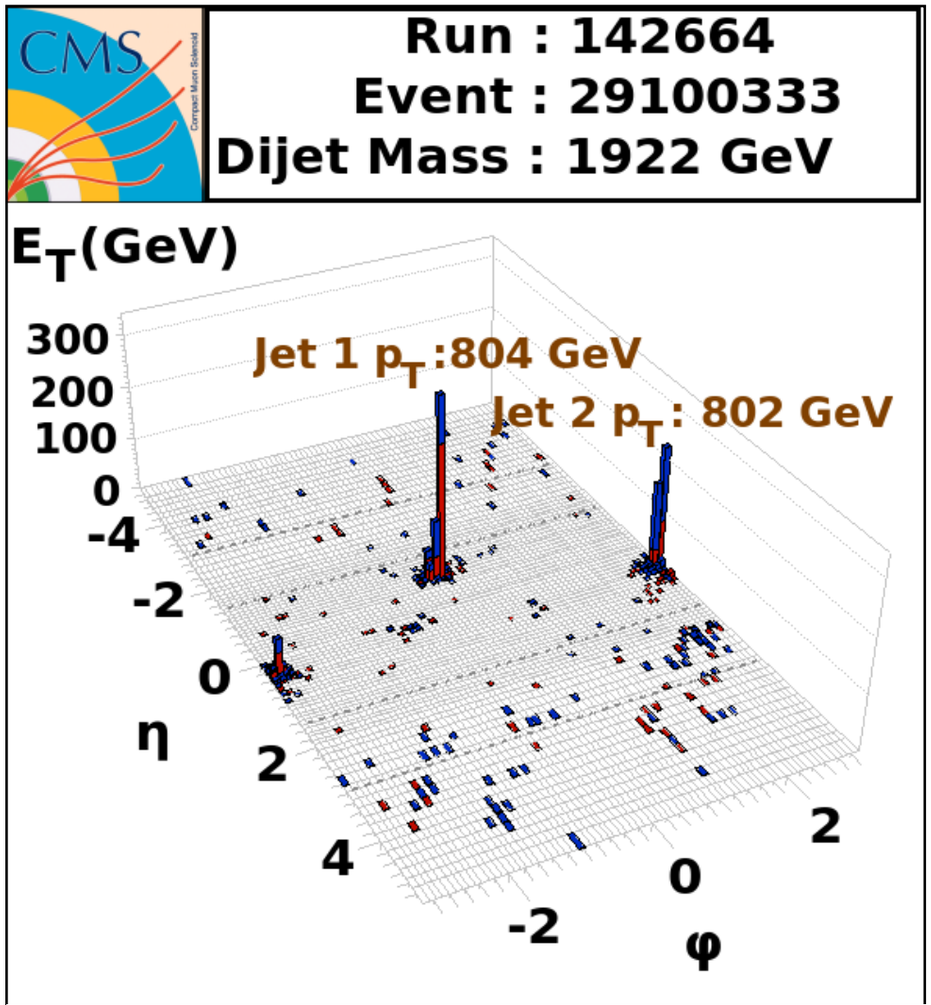
Dijet in Standard Model

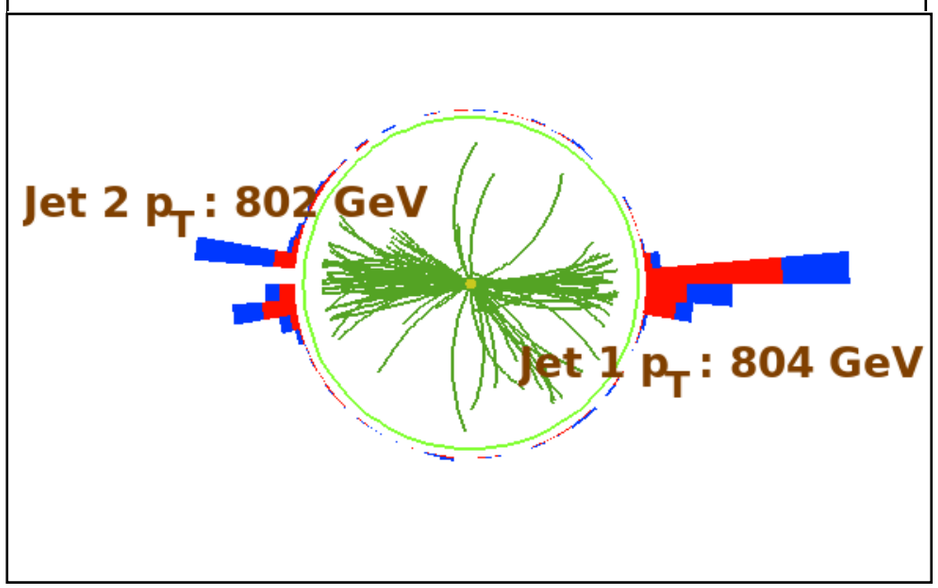


$$\sigma(P_1,P_2)=\sum_{i,j}\int dx_1 dx_2 f_i(x_1,\mu^2) f_j(x_2,\mu^2)\hat{\sigma}_{ij}(p_1,p_2,\alpha_s(\mu^2),Q^2/\mu^2)$$

- What is a Dijet?
  - ✓ Dijet results from simple 2→2 scattering of "partons", dominant process
  - ✓ Dijet is the two leading jets in an event

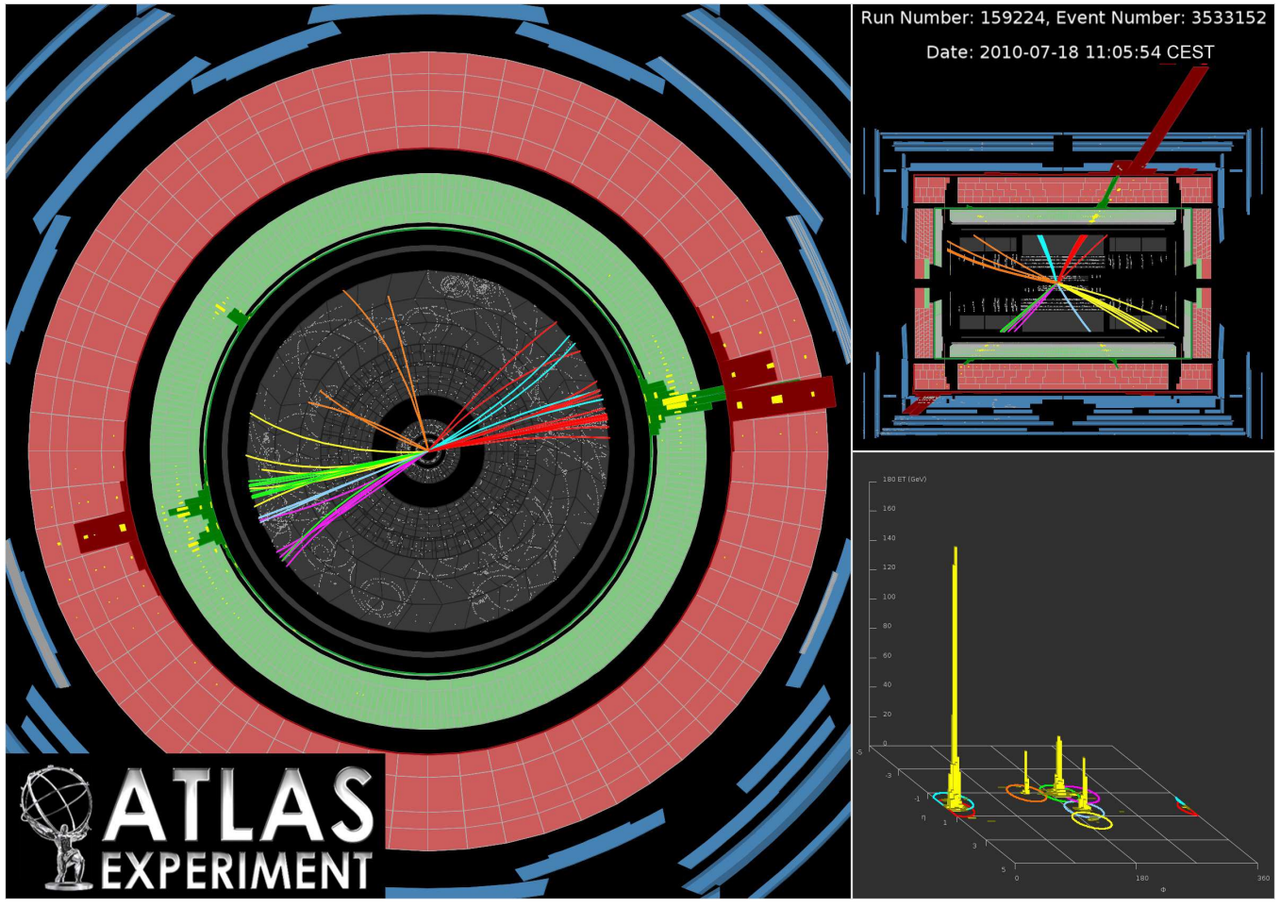
Event Display





The highest-m^{jj} central event observed

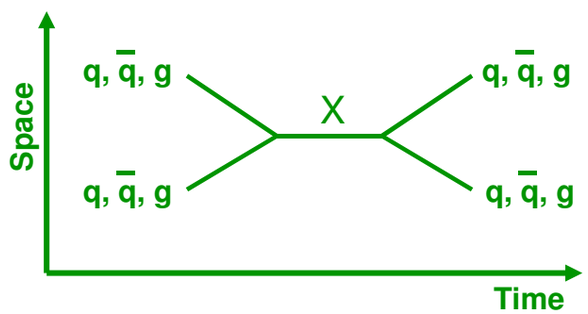
$m^{jj} = 1.77$ TeV. $p_T^{j1} = 1.1$ TeV. $p_T^{j2} = 480$ GeV, partly in calorimeter gap.

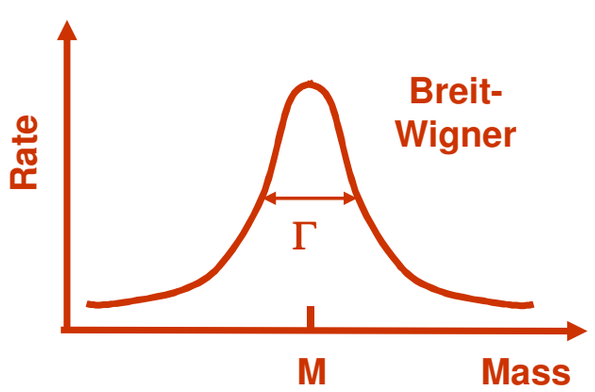


$$m = \sqrt{(E_1 + E_2)^2 - (\vec{p}_1 + \vec{p}_2)^2}$$

Resonance Models

Model Name	X	Color	J^P	$\Gamma/(2M)$	Chan
Excited Quark	q*	Triplet	$1/2^+$	0.02	qg
E_6 Diquark	D	Triplet	0^+	0.004	qq
Axigluon	A	Octet	1^+	0.05	$q\bar{q}$
Coloron	C	Octet	1^-	0.05	$q\bar{q}$
RS Graviton	G	Singlet	2^+	0.01	$q\bar{q}$, gg
Heavy W	W′	Singlet	1^-	0.01	$q\bar{q}$
Heavy Z	Z′	Singlet	1^-	0.01	$q\bar{q}$
String	S	mixed	mixed	$0.003 - 0.037$	$q\bar{q}$, qq, gg and qg





- The models are listed.
  - ✓ Produced in “s-channel”
  - ✓ Parton-Parton Resonances
    - Observed as dijet resonances.
- Search for model with narrow width Γ.
- ATLAS has only searched for excited quark model.
- CMS has searched for the all models.

Experimental Technique

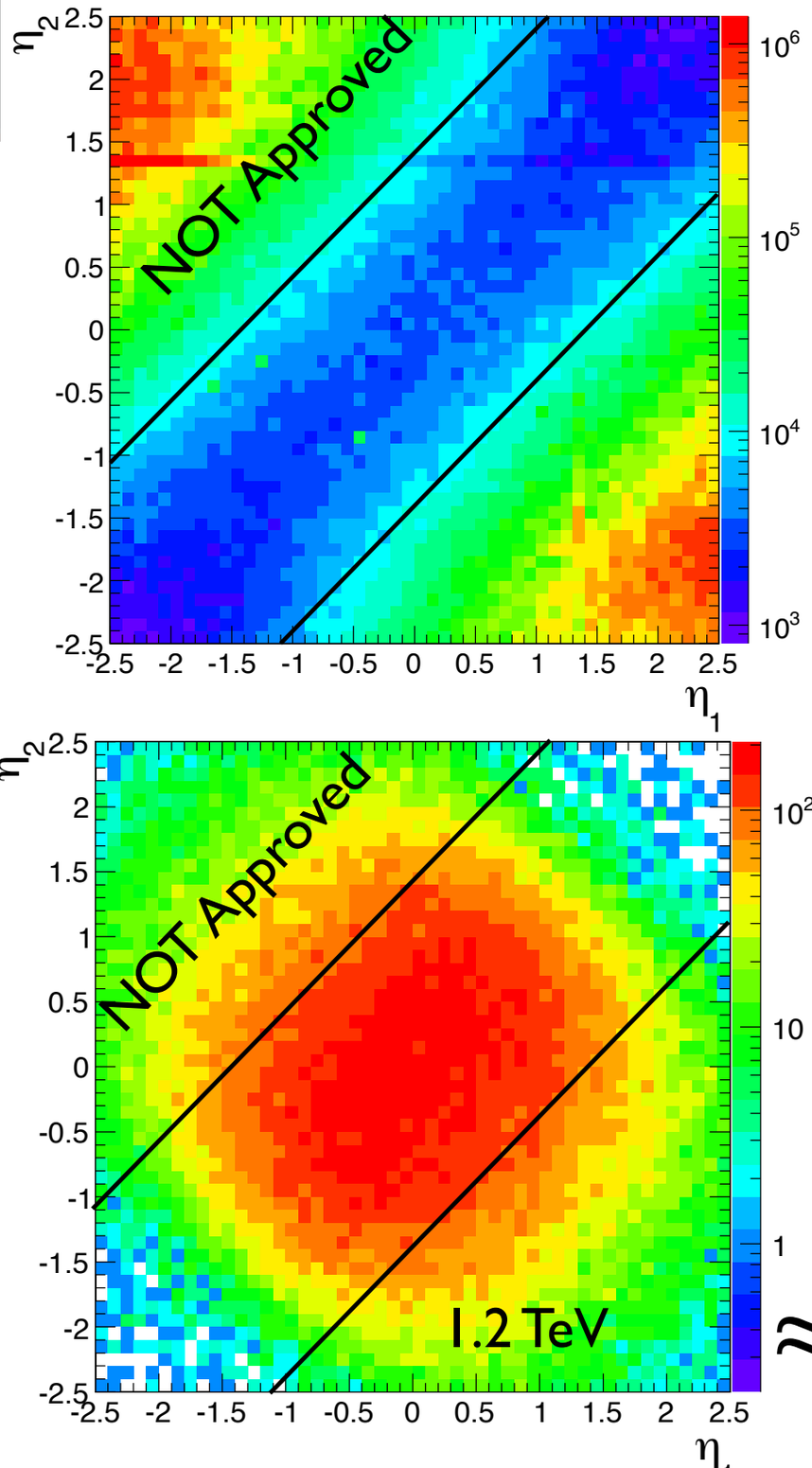
- Measurement of dijet mass spectrum
- Comparison to PYTHIA QCD Monte Carlo prediction
- Fit of the measured dijet mass spectrum with a smooth function and search for resonance signal (bump)
- If no evidence, calculate model independent cross section upper limit and compare with any model cross section.

Event Selection

- CMS standard event quality cuts
- At least two jets
- Anti-kt R=0.7
- CMS jet quality cuts
- M_{jj}>220 GeV
- $|\eta|<2.5$ & $|\Delta\eta|<1.3$

- ATLAS standard event quality cuts
- At least two jets
- Anti-kt R=0.6
- ATLAS jet quality cuts
- P_T(jet1)>80 GeV and P_T (jet2)>30 GeV
- M_{jj}>200 GeV
- $|\eta|<2.5$ & $|\Delta\eta|<1.3$

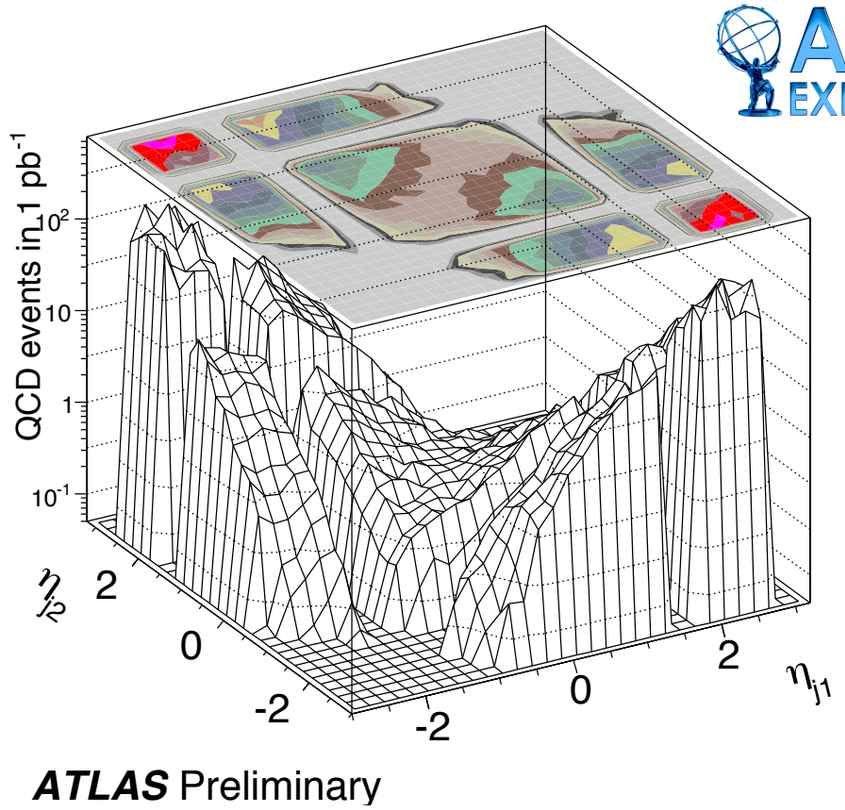
Eta Cut Optimization

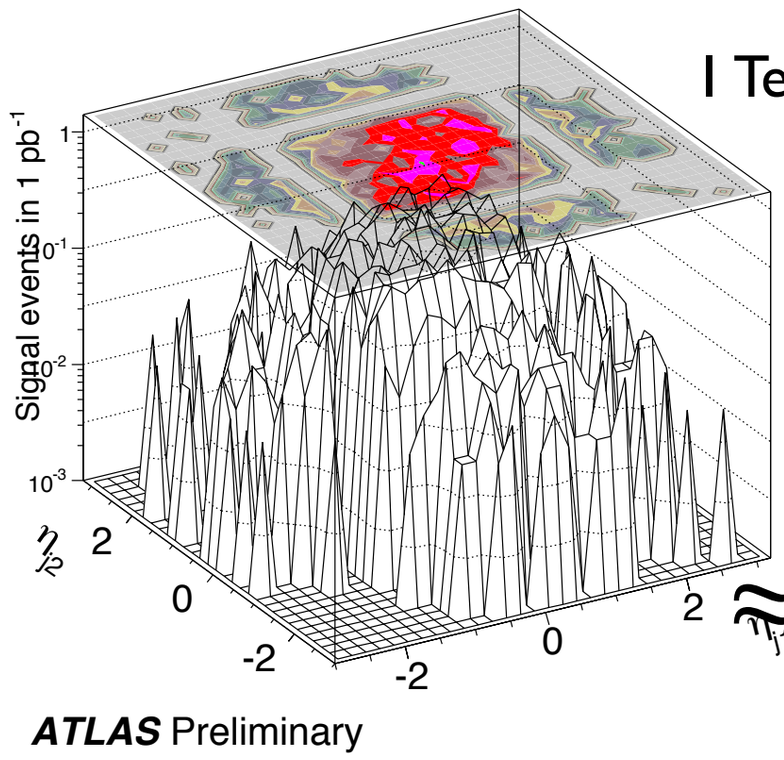


QCD MC

q*

≈60%





≈50%

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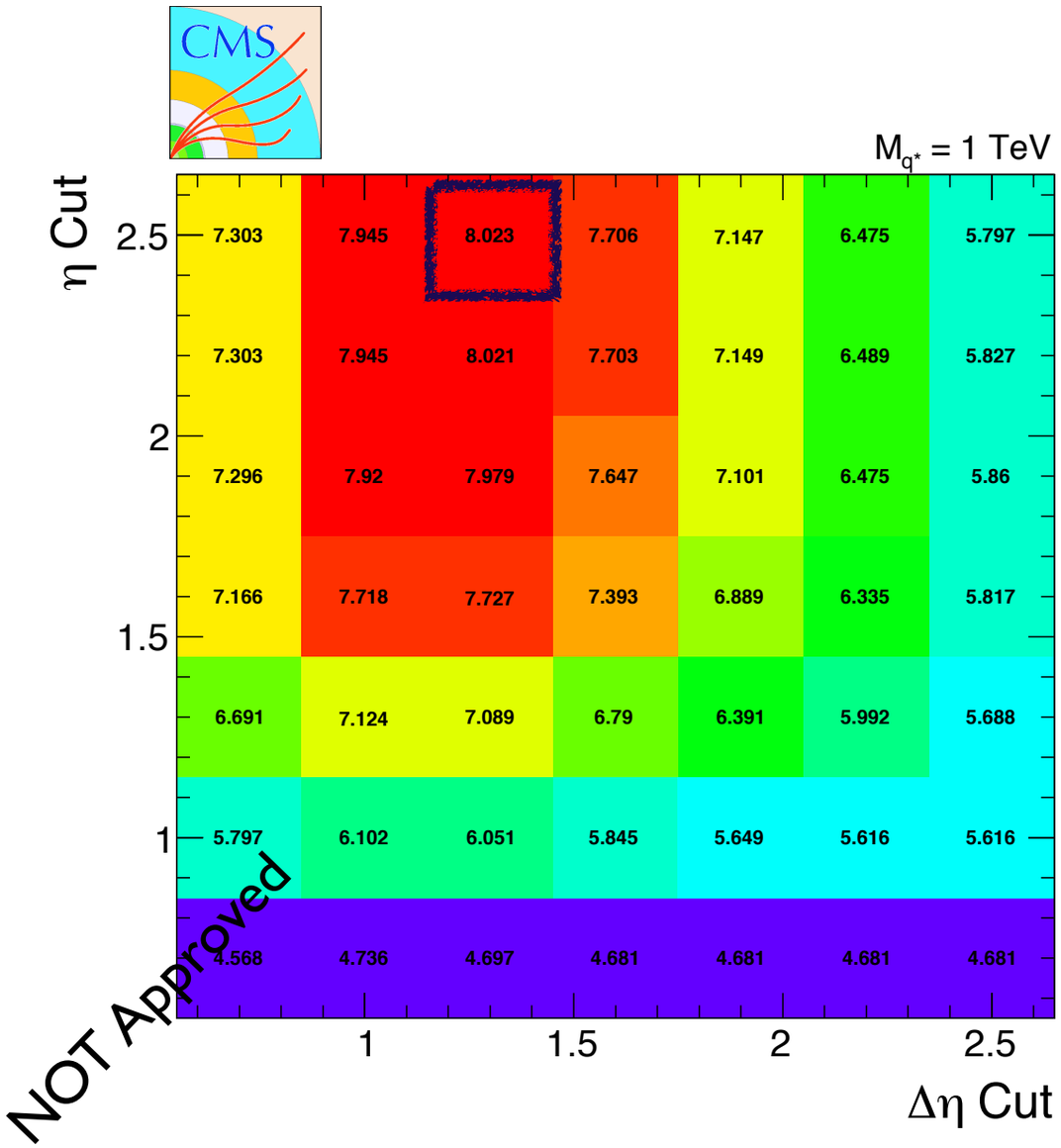
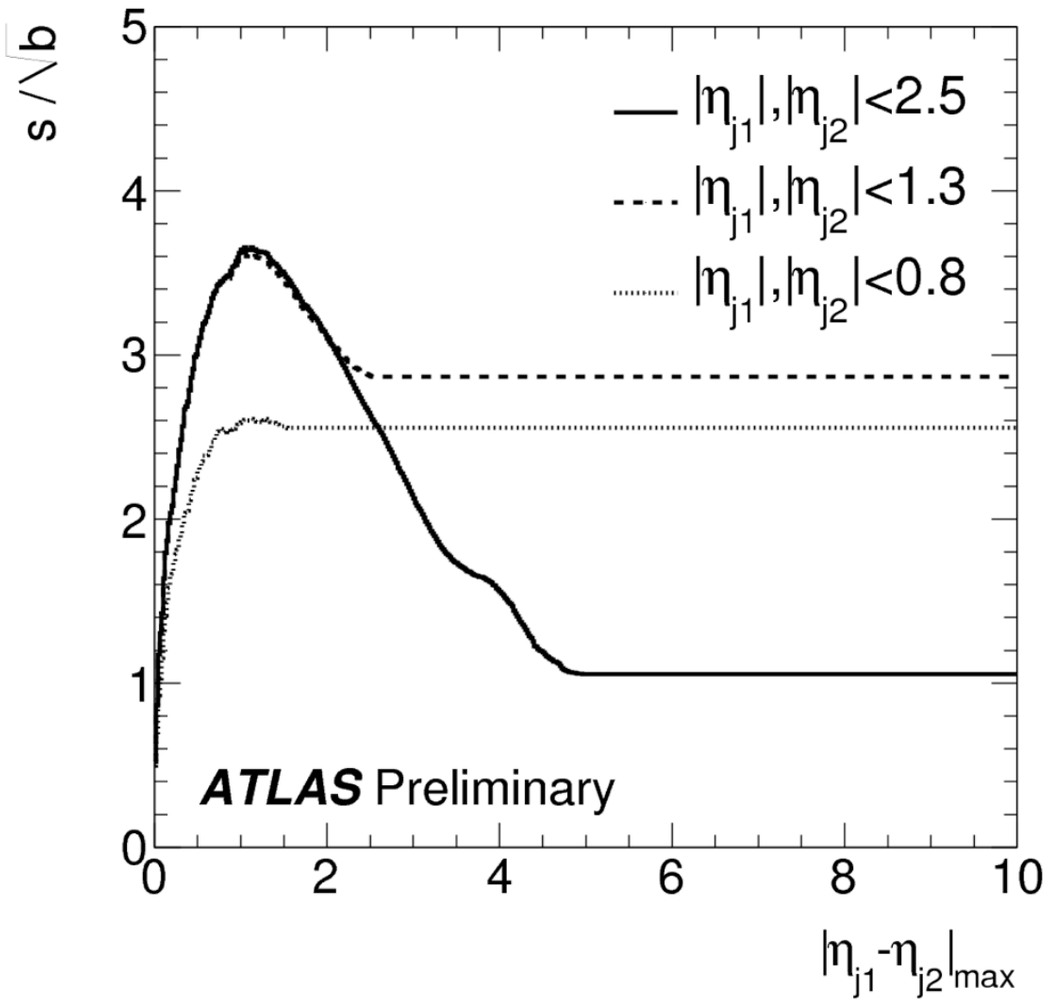
Eta Cut Optimization-II

- $|\Delta\eta|$ cut directly removes QCD t-channel pole in center of mass.
- $|\Delta\eta| < 1.3$ optimal for isotropic decays (q*).





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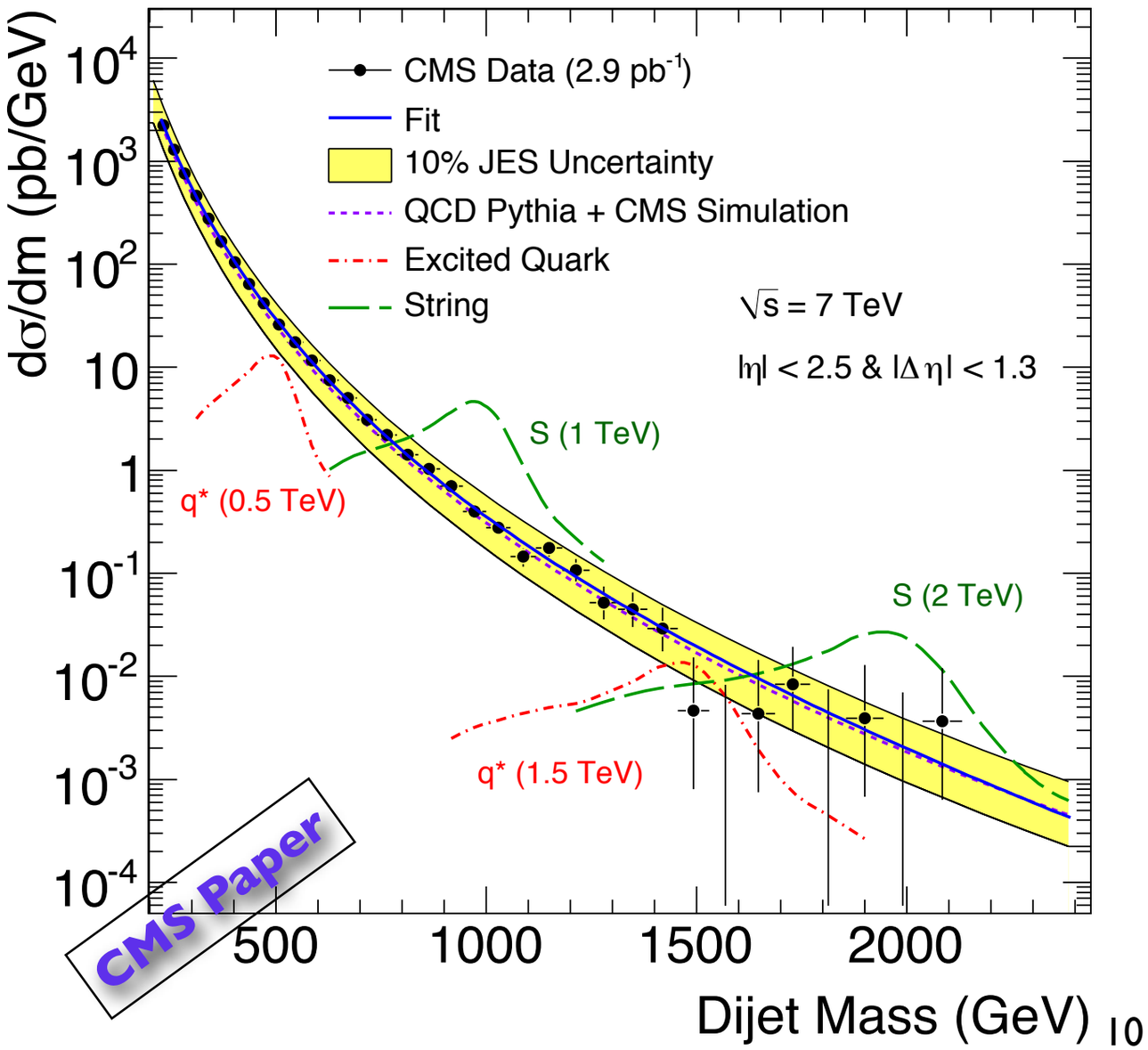
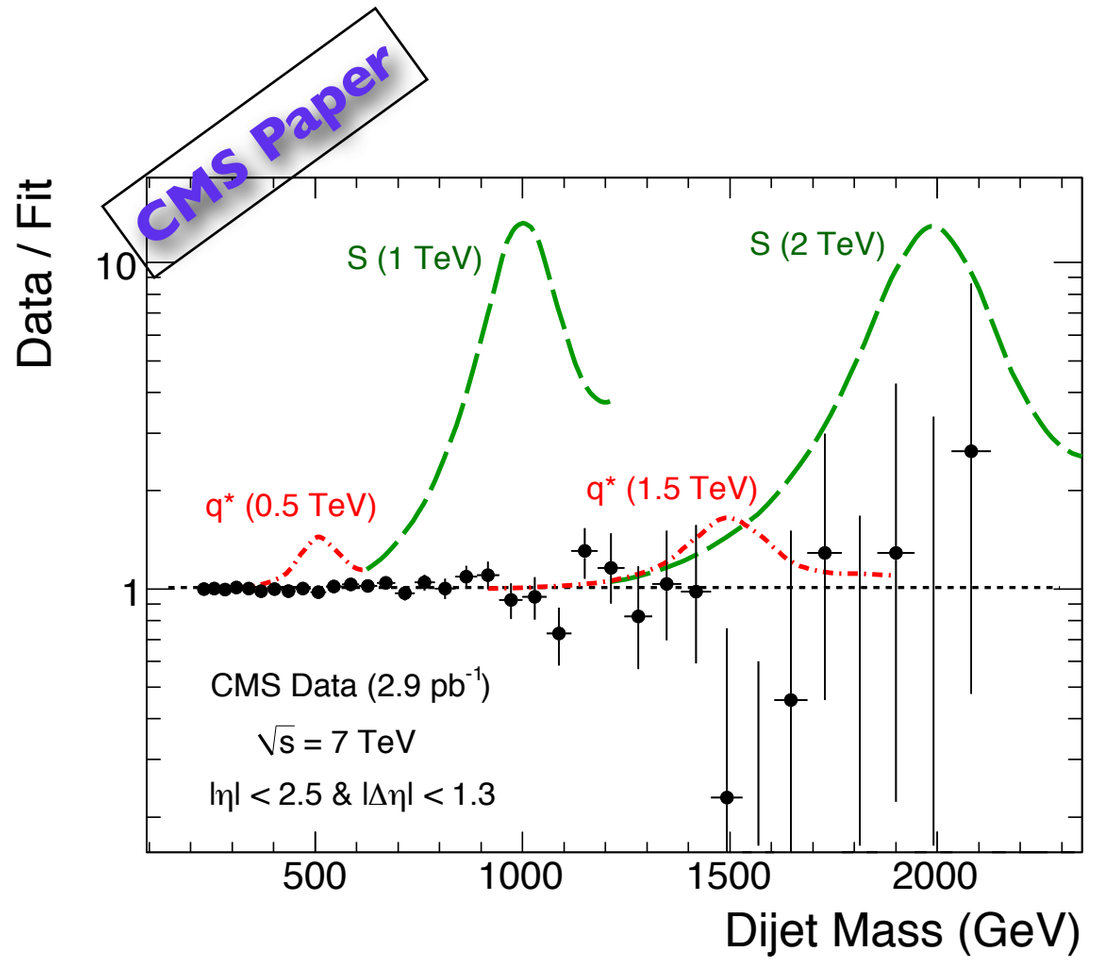
Dijet Mass (CMS)

- Both CMS and ATLAS fit the data to a function containing 4 parameters used by CDF Run II.
- Variable Dijet mass bin which are equal to dijet mass resolution of signal. (from 10% at 0,5 TeV to 6% at 2.5 TeV)
- There is a good fit.
- No evidence of new physics

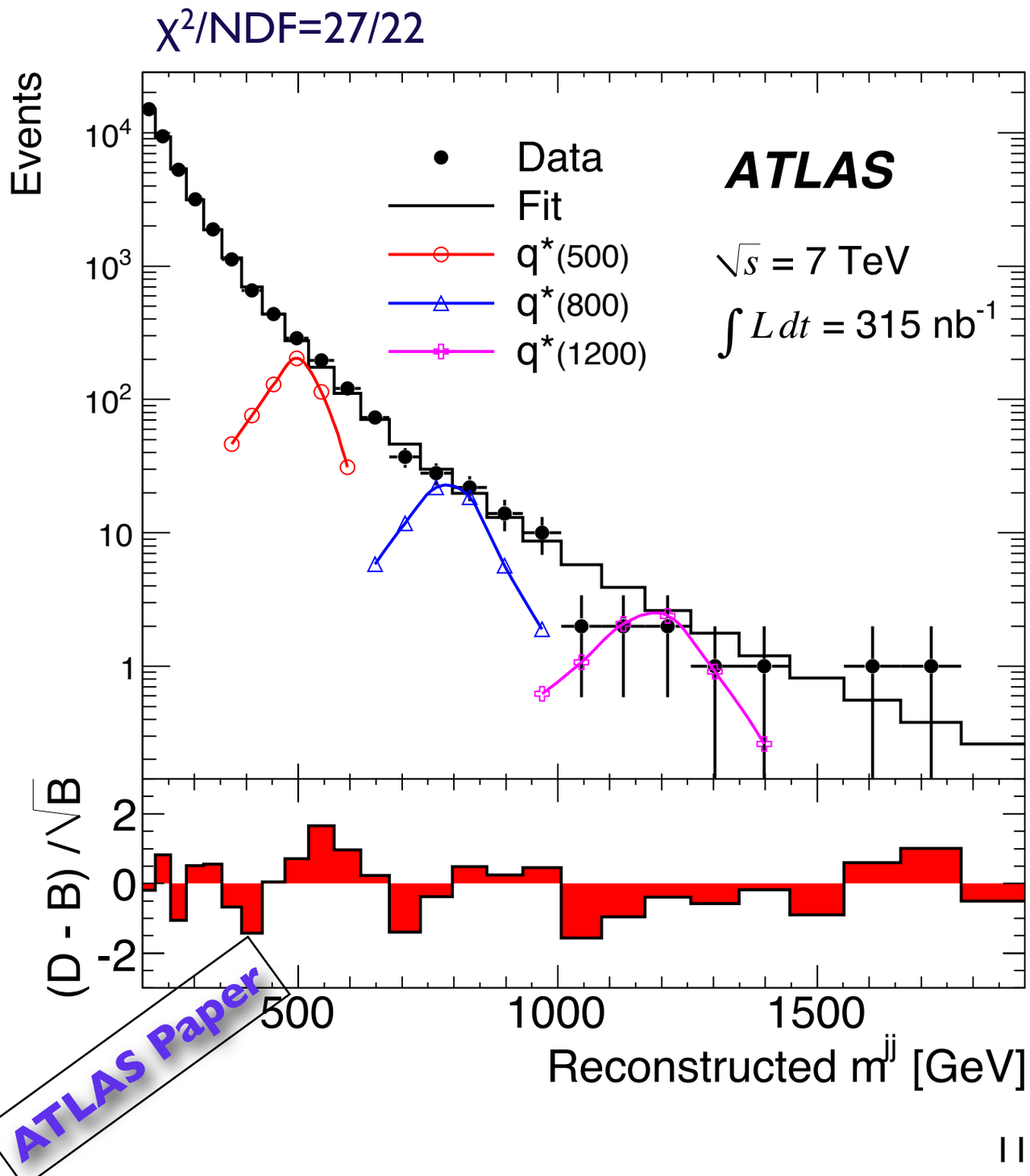
χ^2/NDF=32/31





$$\frac{d\sigma}{dm} = p_0 \frac{(1-X)^{p_1}}{X^{p_2+p_3\ln(X)}} \qquad x = m_{jj}/\sqrt{s}$$

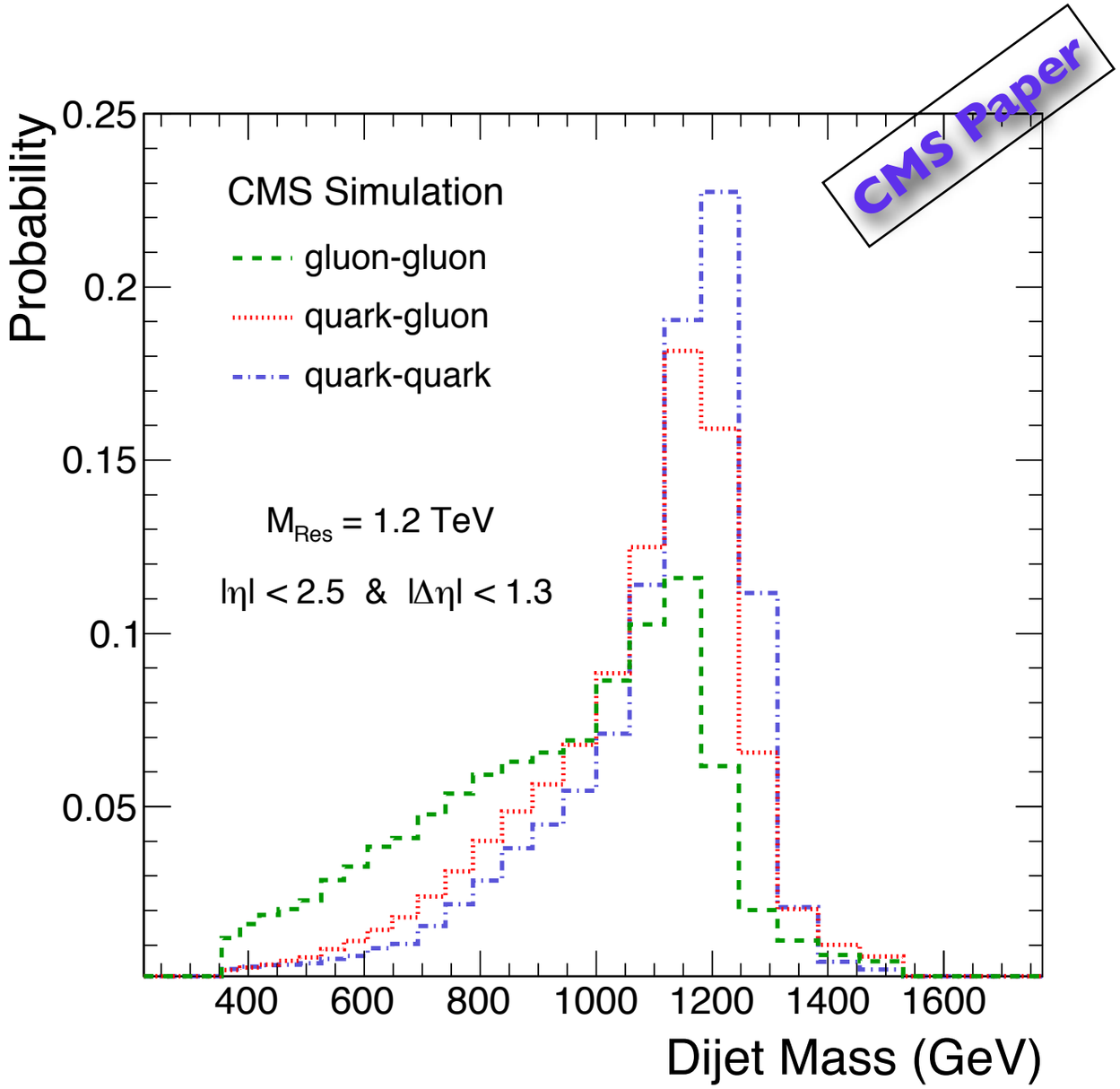
Dijet Mass (ATLAS)



- The same fit function used by CDF Run II.
- The choice of dijet mass binning was motivated by the dijet mass resolution of the signal. (from 11% at 0.3 TeV to 7% at 1.7 TeV)
- There is good fit.
- No evidence of new physics.

$$\frac{d\sigma}{dm} = p_0 \frac{(1-X)^{p_1}}{X^{p_2+p_3\ln(X)}} \qquad x = m_{jj}/\sqrt{s}$$

Resonance Shape



- CMS have simulated dijet resonances using CMS simulation + PYTHIA.
- qq, qg and gg resonances have different shape mainly due to FSR.
  - ✓ The width of dijet resonance increases with number of gluons because gluons emit more radiation than quarks.
- CMS search for these three basic types of narrow dijet resonance in our data.

Setting Limits

- For setting upper limit on the resonance production cross section, a Bayesian formalism with a uniform prior is used by CMS and ATLAS.

$$L = \prod_i \frac{\mu_i^{n_i} e^{-\mu_i}}{n_i!} \qquad \mu_i = \alpha N_i(S) + N_i(B).$$

- n_i: Measured # of events in data
- $N_i(S)$: # of event from signal
- $N_i(B)$: Expected # of event from background

- The signal comes from our dijet resonance shapes.
- The background comes from fixed to the best Background+Signal fit.
- The 95% CL upper limits are calculated for resonances with various masses.

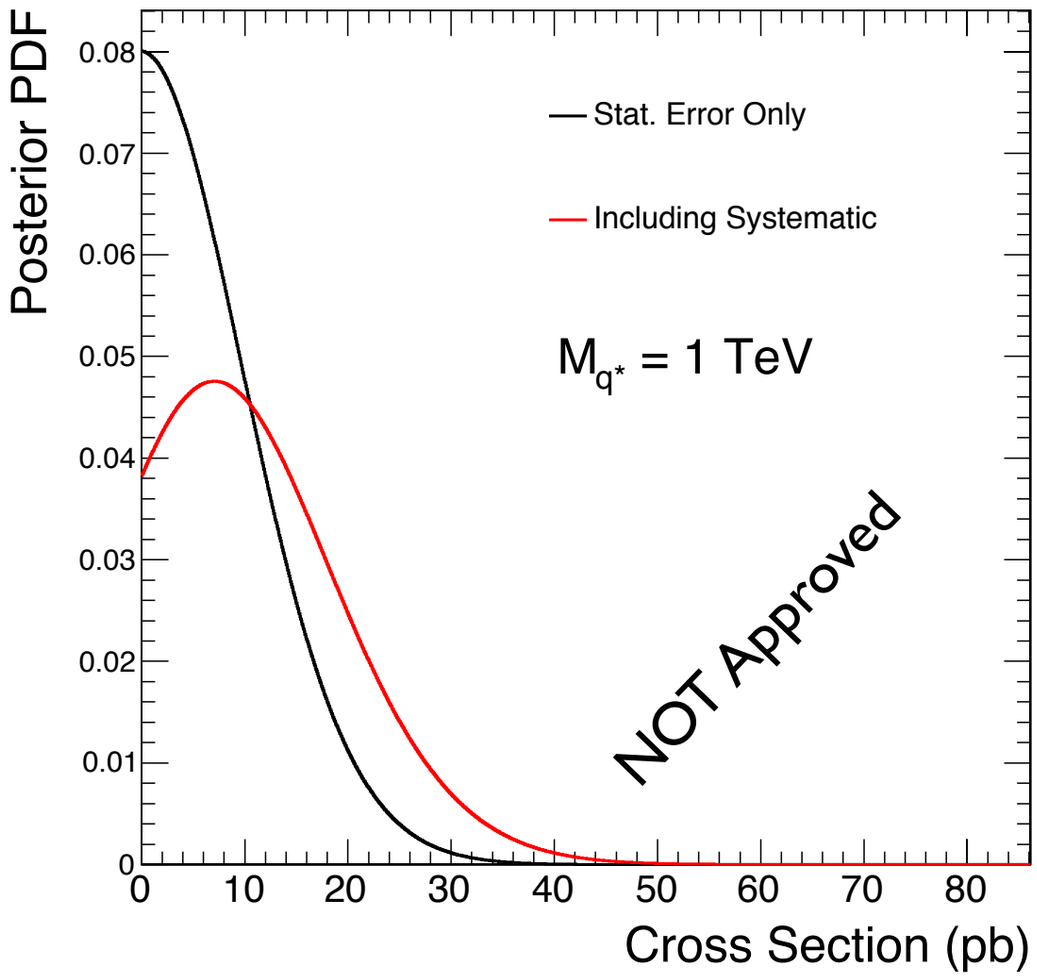
Systematics

- We found the uncertainty in dijet resonance cross section from following sources.
  - ✓ Jet Energy Scale (JES)
    - 10% for CMS
    - from 10% to 6% as a function of Pt for ATLAS
  - ✓ Jet Energy Resolution (JER)
    - 10% for CMS
    - 14% for ATLAS
  - ✓ Choice of Background Parametrization
  - ✓ Luminosity
    - 11% for both CMS and ATLAS
- The all effects of systematics were incorporated as nuisance parameters.
- The posterior probability density for the cross section is broadened by convoluting it.

Incorporating Systematic

- We convolute posterior PDF with Gaussian systematics uncertainties.

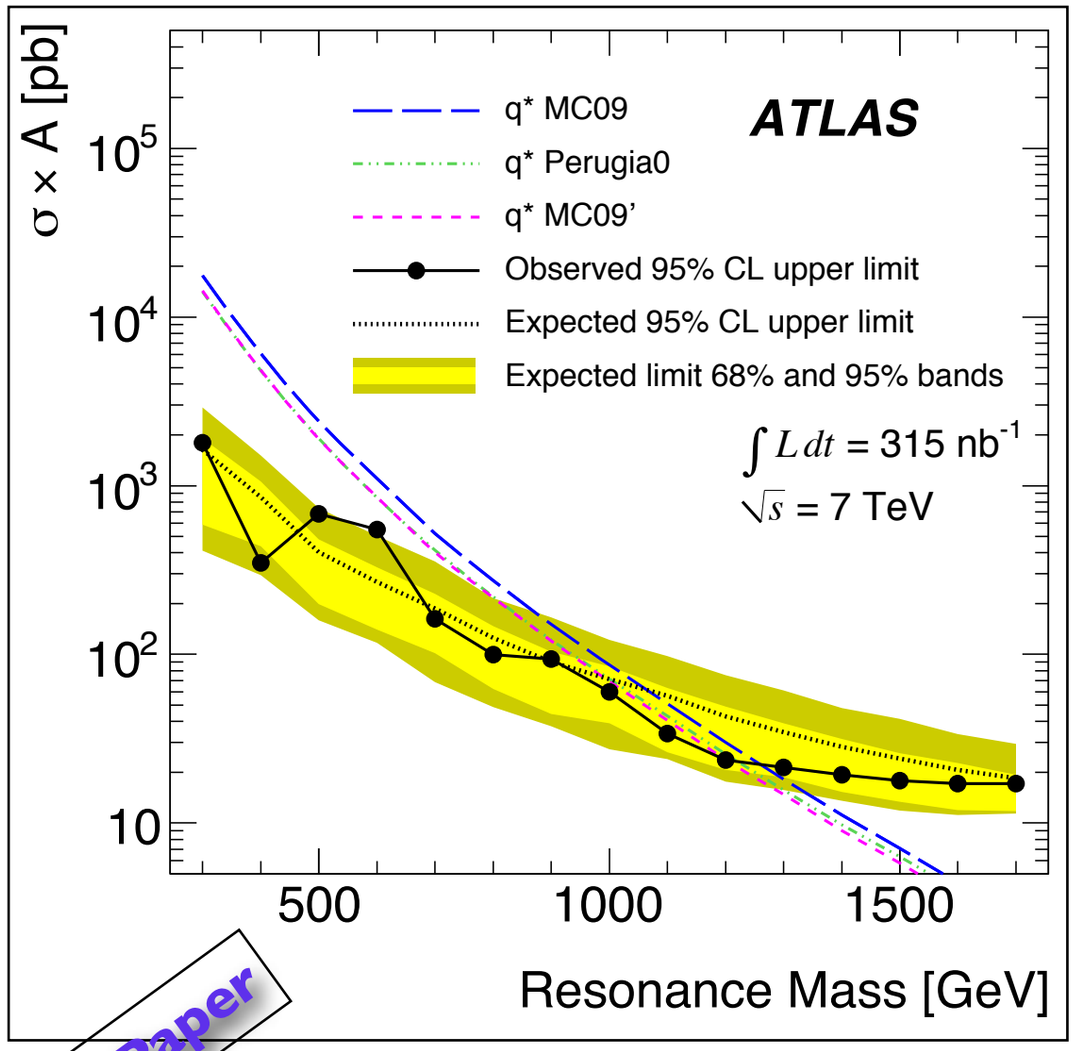
  ✓ Posterior PDF including systematics is broader and gives higher upper limit.



$$L(\sigma) = \int_0^{\infty} L(\sigma')G(\sigma,\sigma')d\sigma'$$

G: Gaussian distribution with RMS width equal to systematic uncertainty in cross section

ATLAS Results



ATLAS Paper

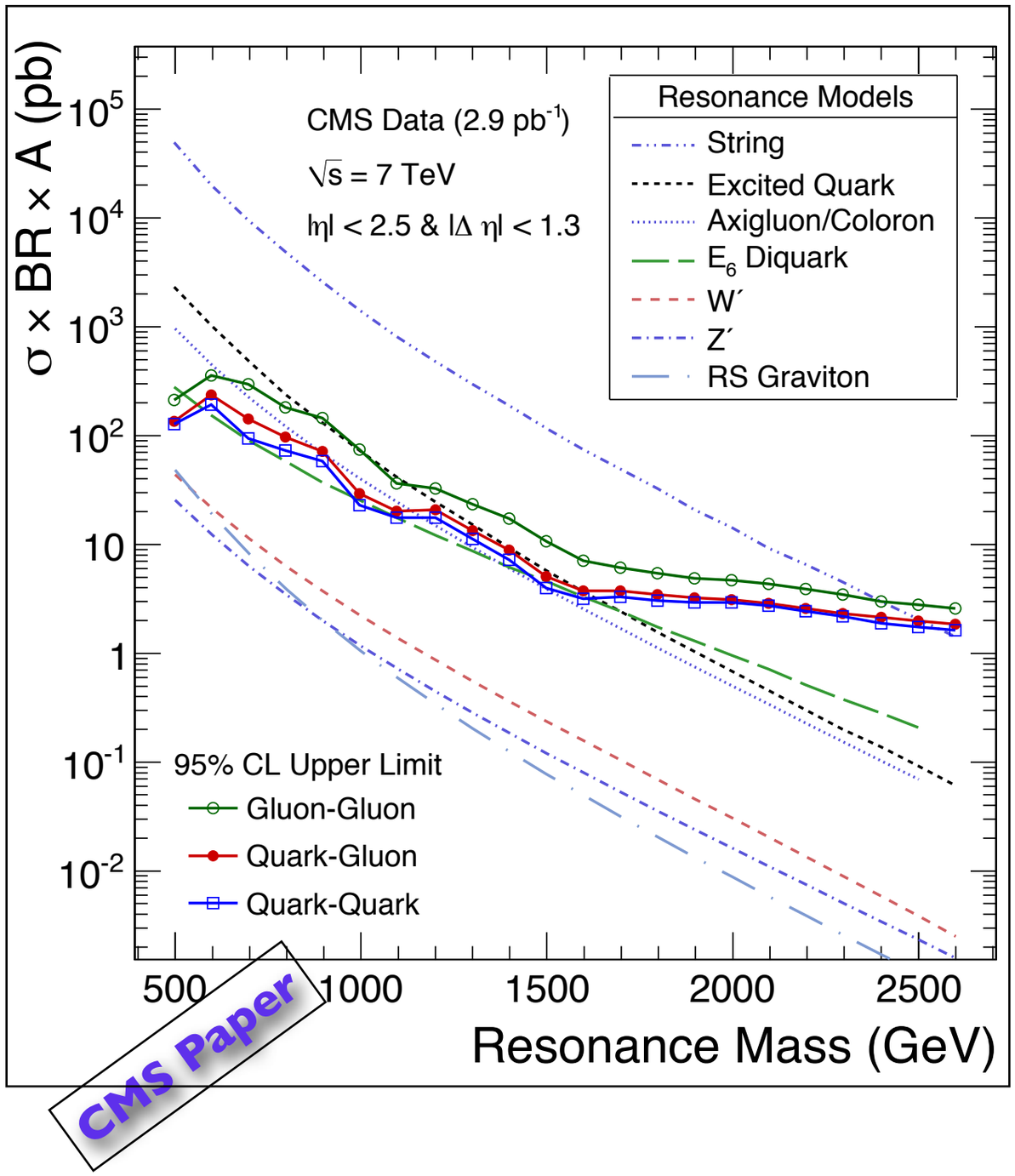
- The mass limits for excited quark based on 315 nb-1 in ATLAS
  - ✓ 0.4<M(q*)<1.26 TeV with MRST2007
  - ✓ 0.4<M(q*)<1.20 TeV with CTEQ6L1
  - ✓ 0.4<M(q*)<1.20 TeV with CTEQ5L
  - ✓ 0.26<M(q*)<0.87 TeV from CDF

TABLE I. The 95% CL lower limits on the allowed q^* mass obtained using different PDF sets.

		Observed Mass Limit [TeV]		Expected Mass Limit [TeV]
MC Tune	PDF Set	Stat. ⊕ Syst.	Stat. only	Stat. ⊕ Syst.
MC09 [27]	MRST2007 [25]	1.26	1.28	1.06
MC09′ [a]	CTEQ6L1 [37]	1.20	1.23	0.99
Perugia0 [39]	CTEQ5L [38]	1.22	1.25	1.00

[a] The MC09′ tune is identical to MC09 except for the PYTHIA [24] parameter PARP(82)= 2.1 and use of the CTEQ6L1 PDF set.

CMS Results



- The mass limits with CTEQ6L1 based on 2.88 pb^{-1} data in CMS:
- **String**
  - ✓ **0.50<M(S)<2.50 TeV**
    - M(S)<1.40 from CDF✣ (1 fb^{-1})
- **Excited Quark**
  - ✓ **0.50<M(q*)<1.58 TeV**
    - 0.40<M(q*)<1.26 from ATLAS (0.32 pb^{-1})
- **Axigluon/Coloron**
  - ✓ **0.50<M(A)<1.17 TeV & 1.47<M(A)<1.52 TeV**
    - 0.12<M(A)<1.25 TeV from CDF✣ (1 fb^{-1})
- **E_6 Diquark**
  - ✓ **0.50<M(D)<0.58 TeV & 0.97<M(D)<1.08 TeV & 1.45<M(D)<1.60 TeV**
    - 0.29<M(D)<0.63 TeV from CDF✣ (1 fb^{-1})

✣T. Aaltonen et al. (CDF), Phys. Rev., D79, 112002 (2009)

Conclusion

- CMS and ATLAS have been searching for dijet resonance.
- The dijet mass data is in good agreement with QCD from PYTHIA.
- There is no evidence for dijet resonances yet.
- CMS and ATLAS have published their results.
- CMS has the best mass limit on dijet resonance models, beyond those published by Tevatron and ATLAS.